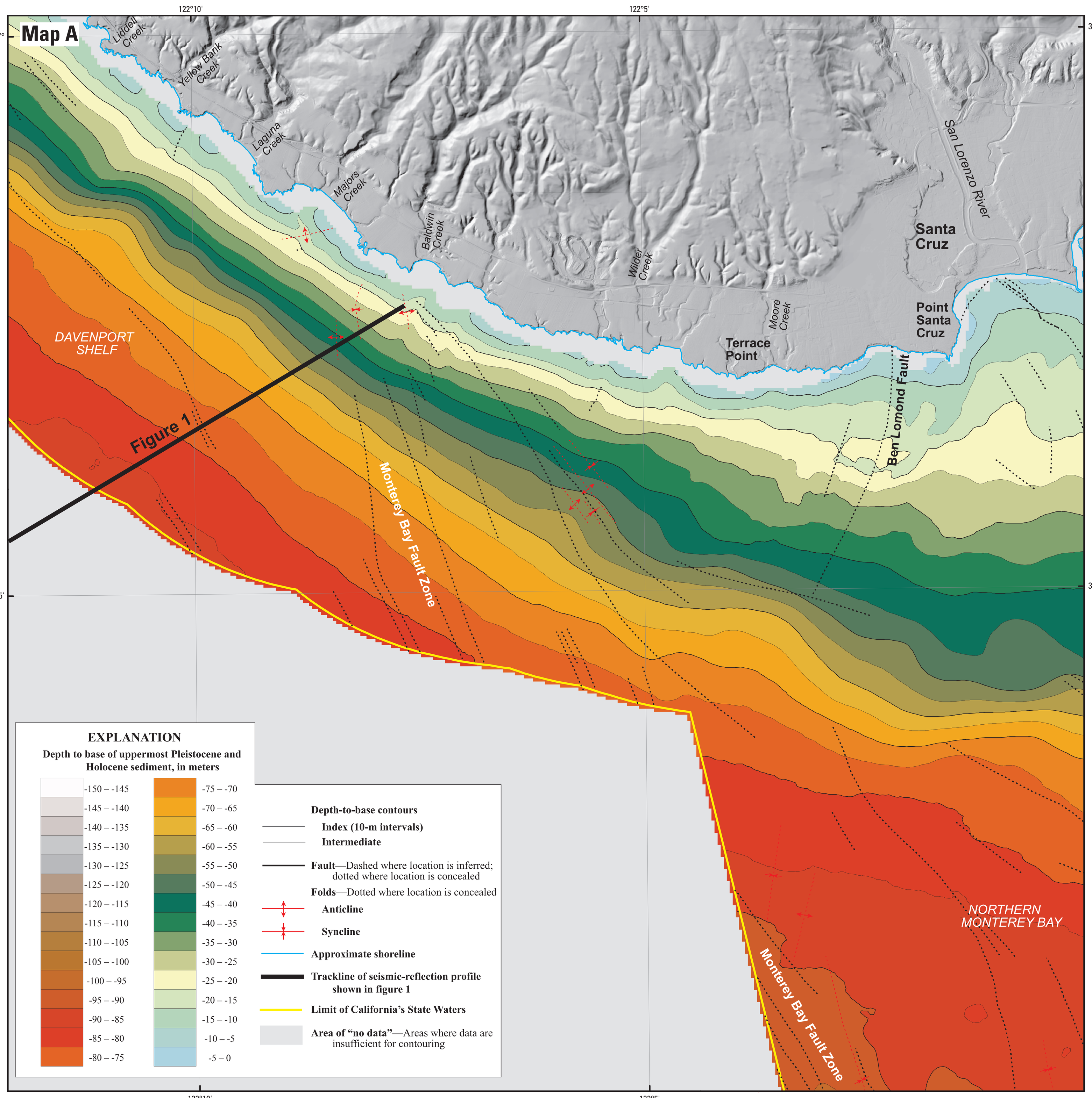

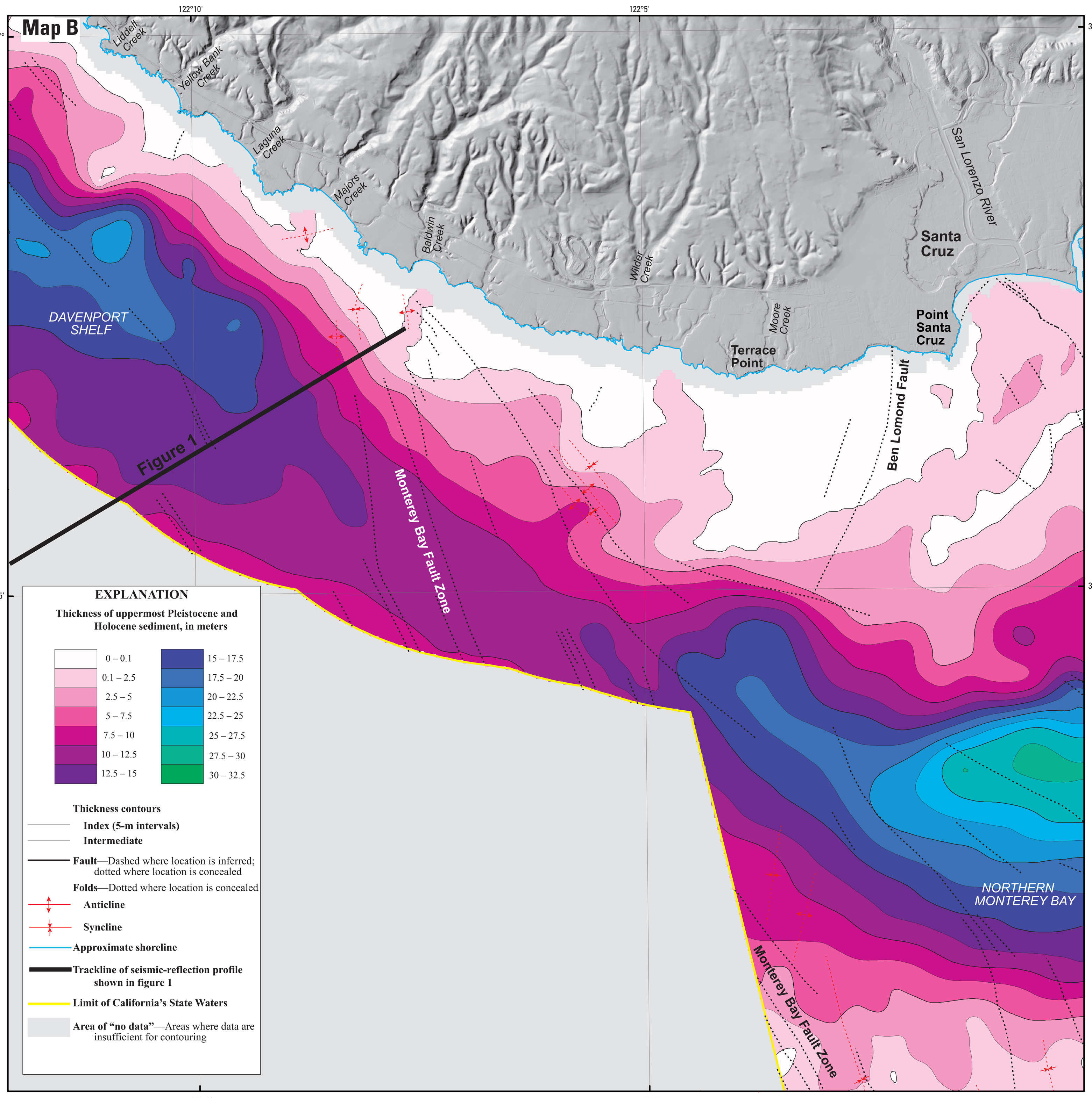

DISCUSSION

This sheet includes maps that show the interpreted thickness and the depth to base of uppermost Pleistocene and Holocene deposits in California's State Waters for the Offshore of Santa Cruz map area (Maps A, B), as well as for a larger area that extends along the coast about 91 km along the coast from Pigeon Point to southern Monterey Bay (Maps C, D) to establish a regional context. High-resolution seismic-reflection profiles (fig. 1; see also, sheet 8) show a lower unit of deformed Neogene bedrock and one or two upper units that consist of upper Quaternary sediments. The bedrock-sediment contact is an angular unconformity that commonly is marked by minor channeling, an eastward onlap onto reflection-free bedrock, and an upward change to lower amplitude, more diffuse reflections. Two upper Quaternary units are recognized on the high-resolution seismic-reflection profiles (fig. 1; see also, figs. 1, 2, 3, 5, 7, 8 on sheet 8). The lower unit (pink shading in profiles) notably includes low-amplitude, low-angle (1° to 3°), offshore-dipping clinoforms (Catuneanu, 2006) that are as thick as 20 m. The upper unit (blue shading in profiles) typically is characterized by low-amplitude, continuous to moderately continuous, diffuse, subparallel reflections, and it has a maximum thickness of about 12 m. Our preferred hypothesis is that the clinoforms in the lower (pink shading) of the two upper Quaternary units represent a progradational delta and (or) shoreface complex that formed between about 30,000 and 21,000 years ago, during the pre–Last Glacial Maximum (LGM) sea-level drop of marine-isotope stage 2 (Waelbroeck and others, 2002). The overlying upper unit (blue shading) represents shelf deposits that formed during the post-LGM sea-level rise of the last about 21,000 years (Stanford and others, 2011). In this interpretation, the surface at the top of the lower, clinoform-bearing unit (pink shading) is a transgressive surface of erosion that formed as the shoreface migrated landward. Because these two upper Quaternary units each consist of unconsolidated upper Quaternary sediments and together overlie the prominent angular unconformity with bedrock, we have combined their thickness on Maps B and D.

To make these maps, water bottom and depth to base of the uppermost Pleistocene and Holocene sediment layer were mapped from seismic-reflection profiles (fig. 1; see also, sheet 8). The difference between the two horizons was exported for every shot point as XY coordinates (UTM zone 10) and two-way travel time (TWT). The thickness of the uppermost Pleistocene and Holocene sediment layer (Maps B, D) was determined by applying a sound velocity of 1,600 m/sec to the TWT. The thickness points were interpolated to a preliminary continuous surface, overlaid with zero-thickness bedrock outcrops (see sheet 10), and contoured, following the methodology of Wong and others (2012).

The thickness of the uppermost Pleistocene and Holocene sediments in the Offshore of Santa Cruz map area ranges from 0 to 32 m (Map B), and the depth to the unconformity at the base of this unit ranges from less than 10 to 92 m (Map A). Mean sediment thickness for the map area is 8.7 m, and the total sediment volume is $1{,}238\times106$ m^3 (table 7–1 in pamphlet).

The thickest sediment in the map area is found in two discrete depocenters that are present along the northwestern and southeastern margins of the map area. The more northwestern of the two depocenters is found south of Davenport (see fig. 1–1 in pamphlet), and it has a maximum sediment thickness of 24 m (Maps B, D). Much of this sediment is part of the lower clinoform-bearing unit (pink shading in profiles; see fig. 1; see also, figs. 1, 2, 3 on sheet 8) of inferred pre-LGM, regressive origin. The upper Quaternary sediments in this depocenter form a lens that thins in both the onshore and offshore directions (see fig. 1), and the axis of the depocenter coincides with an offshore decrease in slope of the underlying unconformity, from about 1.0° to 0.5°. The thicker sediment effectively fills the accommodation space above the slope change, so that the modern continental shelf has a relatively smooth, offshore-dipping (about 0.7° to 0.8°) surface. This depocenter is not present at the mouths of significant coastal watersheds; the clinoforms are, thus, inferred to represent an offshore-prograding shoreface, rather than prograding delta foresets.

The unnamed, more southeastern of the two depocenters is present offshore of the San Lorenzo River, about 8 km south of Santa Cruz in northwestern Monterey Bay, and it has maximum sediment thickness of 32 m (Map B). As with the northeastern depocenter, thicker sediments form an onshore- and offshore-dipping lens, and much of its thickness (as much as 20 m) results from the presence of inferred pre-LGM, offshore-dipping clinoforms (see, for example, figs. 7, 8 on sheet 8). This depocenter also is centered in the accommodation space created by an offshore decrease in slope (from about 1.5° to about 0.5°) of the underlying angular unconformity (Map D). Both the local thickness of the inferred pre-LGM unit and the location of the depocenter offshore of the San Lorenzo River (Map B) suggest that the larger clinoforms in this depocenter formed as part of a prograding delta.

This pre-LGM, regressive unit should have formed along the entire coast in the map area, but it is not present in a small area between the two depocenters (see, for example, fig. 5 on sheet 8) where the slope on the underlying unconformity is more uniform (Map D). In this area, the pre-LGM, regressive unit presumably was locally eroded during the post-LGM transgressive sea-level rise.

Six different informal "domains" of thickness of uppermost Pleistocene to Holocene sediment (see table 7–1 in pamphlet) are recognized on the regional sediment-thickness map (Map D), each with its own diverse set of geologic and (or) oceanographic controls. Note that data from within the Monterey Canyon system (including Soquel Canyon), in the southern part of the Pigeon Point to southern Monterey Bay region, were excluded from this analysis because available seismic-reflection data are insufficient to map sediment distribution in this extremely variable environment.

(1) The southern Monterey Bay domain is bounded by the Monterey Bay shoreline on the south and east, the Monterey Canyon on the north, and the limit of California's State Waters on the west. Sediment derived from the Salinas River forms a large, shore-parallel, subaqueous delta (thickness of as much as 32 m) that progrades across a thinly sediment-mantled bedrock shelf. Small changes in sediment thickness on the shelf are controlled by irregular bedrock relief that is at least partly attributable to the Monterey Bay Fault Zone (Greene, 1990).

(2) The northern Monterey Bay domain is bounded on the south by Monterey Canyon, on the north and east by the Monterey Bay shoreline, and on the west by the limit of California's State Waters. The head of Monterey Canyon extends nearly to the shoreline, and the canyon forms a sediment trap that effectively separates the littoral- and shelf-sediment transport systems of the two (northern and southern) Monterey Bay domains. The northern Monterey Bay domain is characterized by (a) a sediment-poor inner shelf cut by paleochannels of the San Lorenzo River, the Pajaro River, and Soquel Creek; (b) a midshelf depocenter that has sediment as thick as 32 m, much of which was deposited in a pre-LGM prograding delta and (or) shoreface complex and was preserved above a decrease in slope on the underlying unconformity; and (c) a midshelf to outer shelf zone in which sediment generally becomes progressively thinner in the offshore direction.

(3) The Davenport shelf domain extends from the northern limit of Monterey Bay northward to the southern margin of the Waddell Creek depocenter (to the north in the Waddell Creek delta domain). The Davenport shelf domain, as well as the three domains farther north, occupy a section of open, wave-dominated coast that is exposed to wave energy higher than that of the Monterey Bay domains to the south. The Davenport shelf domain includes the Davenport depocenter, a prominent midshelf, shore-parallel depocenter present between Davenport and Santa Cruz that mostly consists of a lower, pre-LGM, clinoform-bearing unit of inferred prograding-shoreface origin. Sediment in this depocenter also is preserved in accommodation space linked to an offshore decrease in the slope of the underlying unconformity. Sediment thickness within the Davenport shelf domain decreases to both the northwest and southeast of this depocenter, owing to the presence of elevated bedrock and (or) the related absence of the lower clinoform-bearing unit.

(4) The Waddell Creek delta domain lies offshore of the mouth of the Waddell Creek coastal watershed, and it is connected to it by a submerged channel. The domain is both distinguished and delineated by the significant Waddell Creek depocenter (maximum sediment thickness of 19 m), which forms a moundlike delta that consists entirely of inferred post-LGM deposits whose primary source is Waddell Creek. Sediment thins both north and south of this moundlike delta; its preservation is attributed to its semiprotected (from erosive wave energy) location on the south flank of Point Año Nuevo.

(5) The Año Nuevo shelf domain lies offshore of Point Año Nuevo, from just north of Franklin Point on the north to just north of the mouth of Waddell Creek on the south. Bedrock exposures, which locally reach water depths of 45 m, cover a substantial part of this wave-exposed domain; in deeper waters farther offshore, sediment cover is relatively thin. Sediment thickness in this domain appears to be limited both by the lack of sediment supply (because of its distance from large coastal watersheds) and by the presence of uplifted bedrock, which is linked to a local zone of transpression in the San Gregorio Fault Zone (Weber, 1990). The uplift has raised this domain and exposed it to the high wave energy that is characteristic of this area (Storlazzi and Wingfield, 2005).

(6) The Pigeon Point shelf domain lies on the west flank of the Pigeon Point high (McCulloch, 1987). Sediment in the Pigeon Point shelf domain is thickest in a shore-parallel band that overlies a slope break in the underlying bedrock surface. Much of the sediment probably was derived from Pescadero Creek, a large coastal watershed that enters the Pacific Ocean about 3 km north of the Pigeon Point to southern Monterey Bay regional map area (see Maps C, D). The Pigeon Point shelf domain is transitional to the Pacifica-Pescadero shelf domain just north of it (see Watt and others, 2014).

Map E shows the regional pattern of major faults and of earthquakes occurring between 1967 and April 2014 that have inferred or measured magnitudes of 2.0 and greater. Fault locations, which have been simplified, are compiled from our mapping within California's State Waters (see sheet 10), from Wagner and others (2002), and from the U.S. Geological Survey's Quaternary fault and fold database (U.S. Geological Survey and California Geological Survey, 2010). Earthquake epicenters are from the Northern California Earthquake Data Center (2014), which is maintained by the U.S. Geological Survey and the University of California, Berkeley, Seismological Laboratory. The M6.9 1989 Loma Prieta earthquake on the San Andreas Fault Zone in the Santa Cruz Mountains (Spudich, 1996) is the most significant event in the region. The largest recorded earthquake in the Offshore of Santa Cruz map area (M4.2, 7/2/1978) occurred within the San Gregorio Fault Zone, about 13 km west of Santa Cruz.

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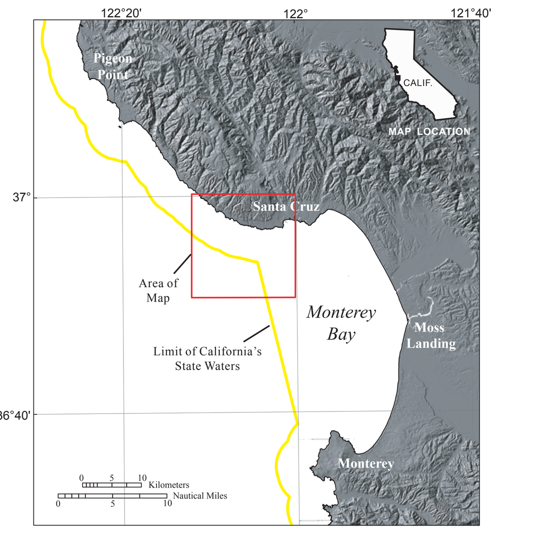


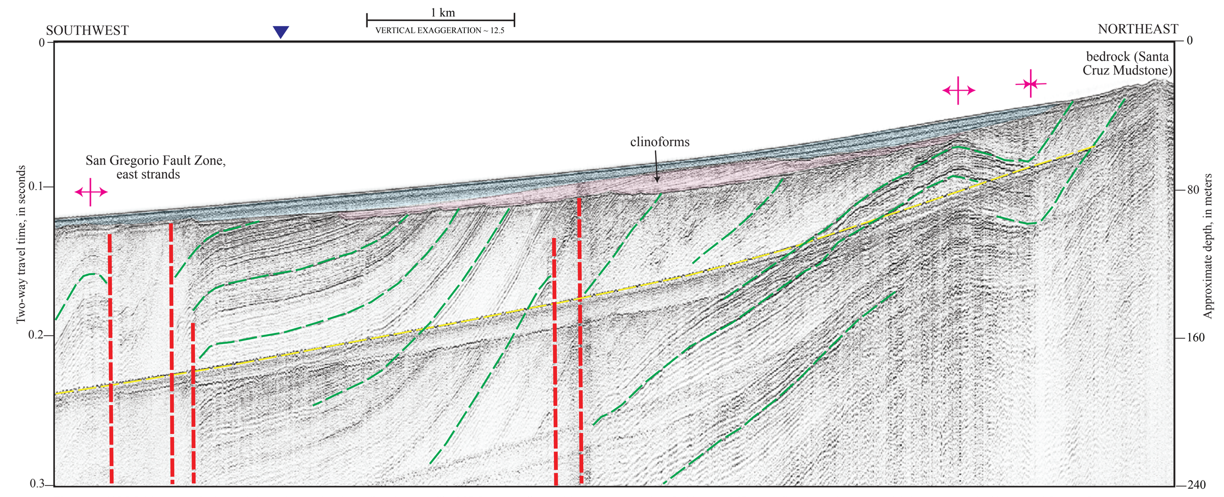
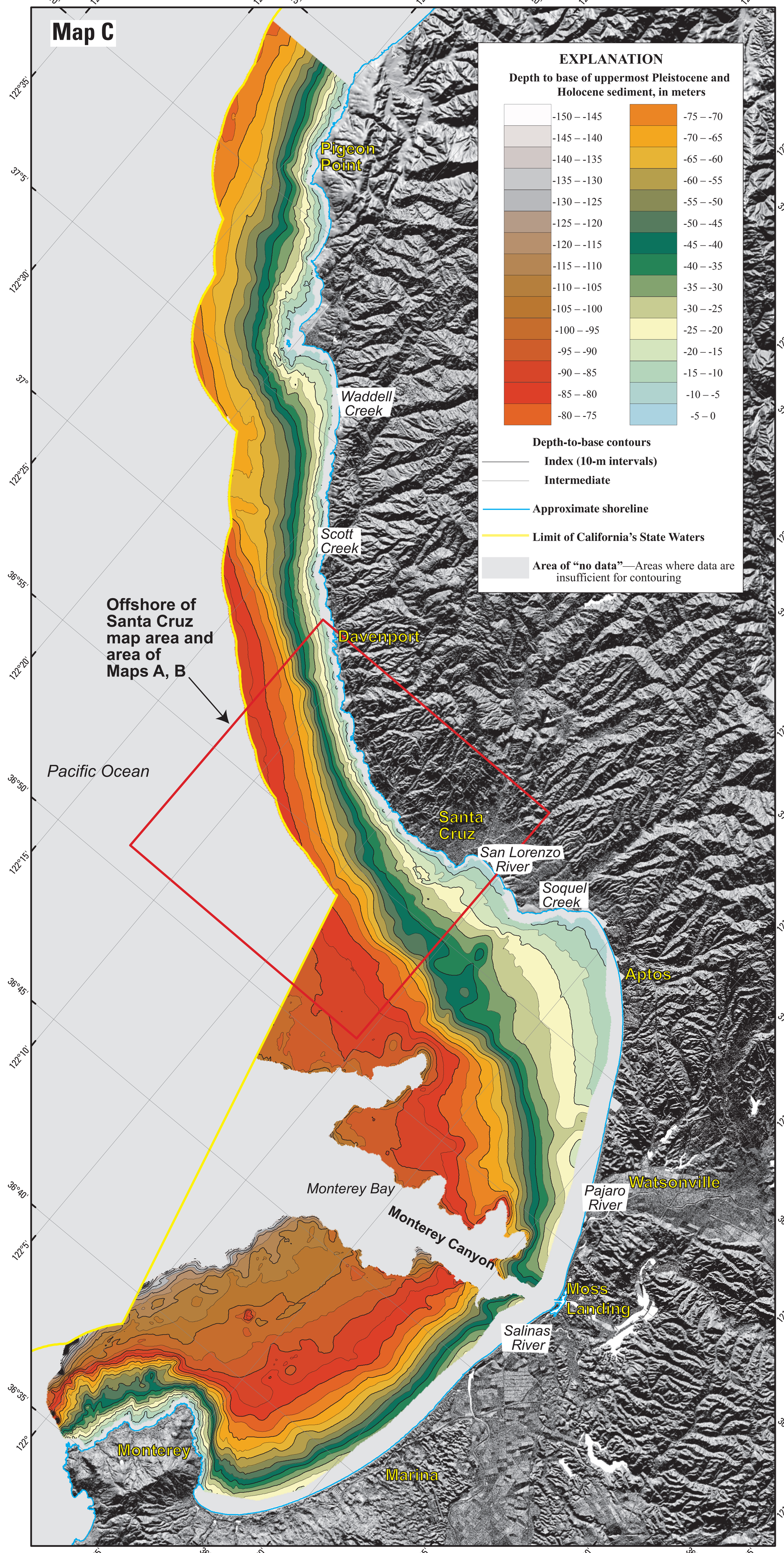
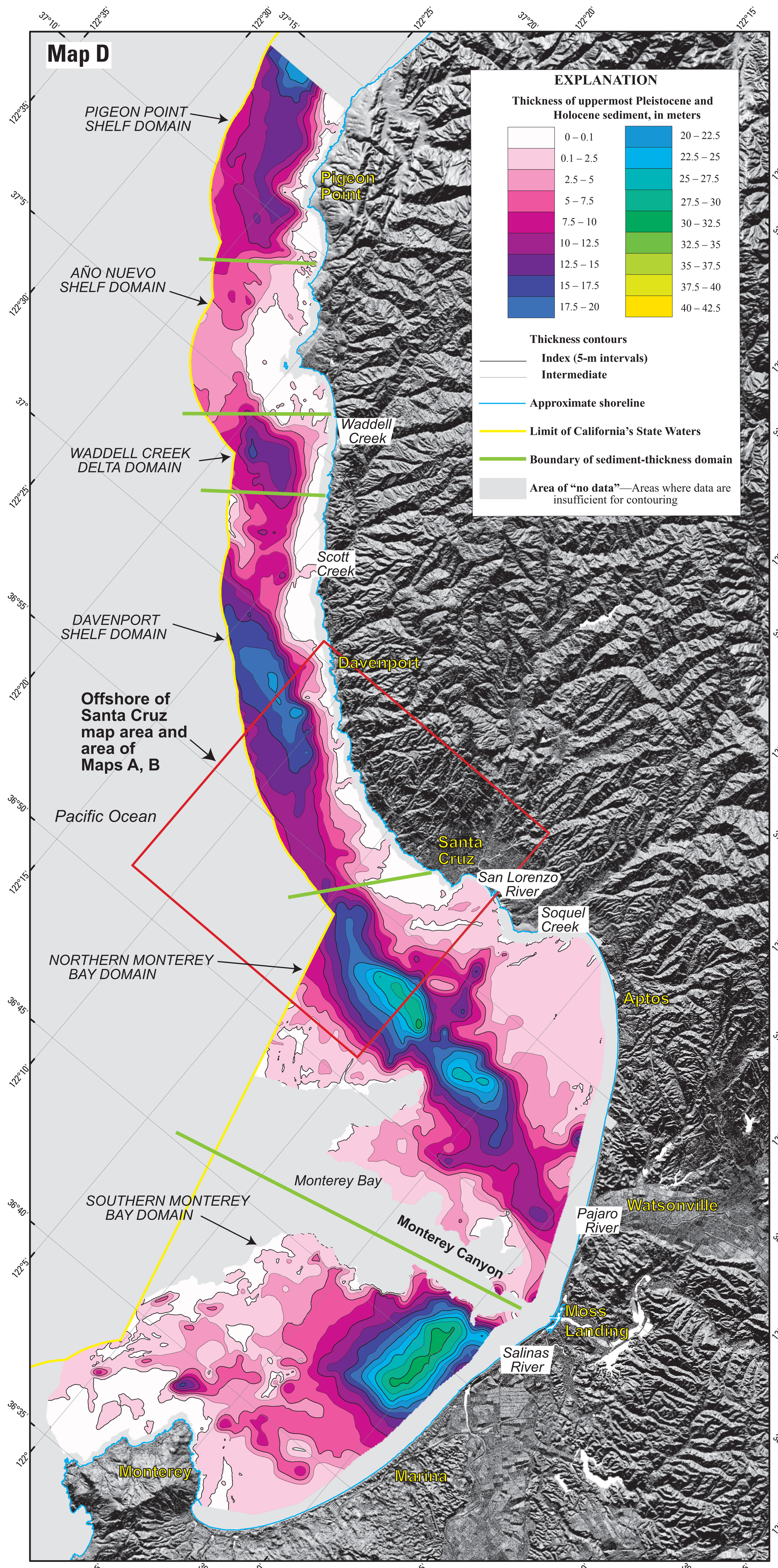
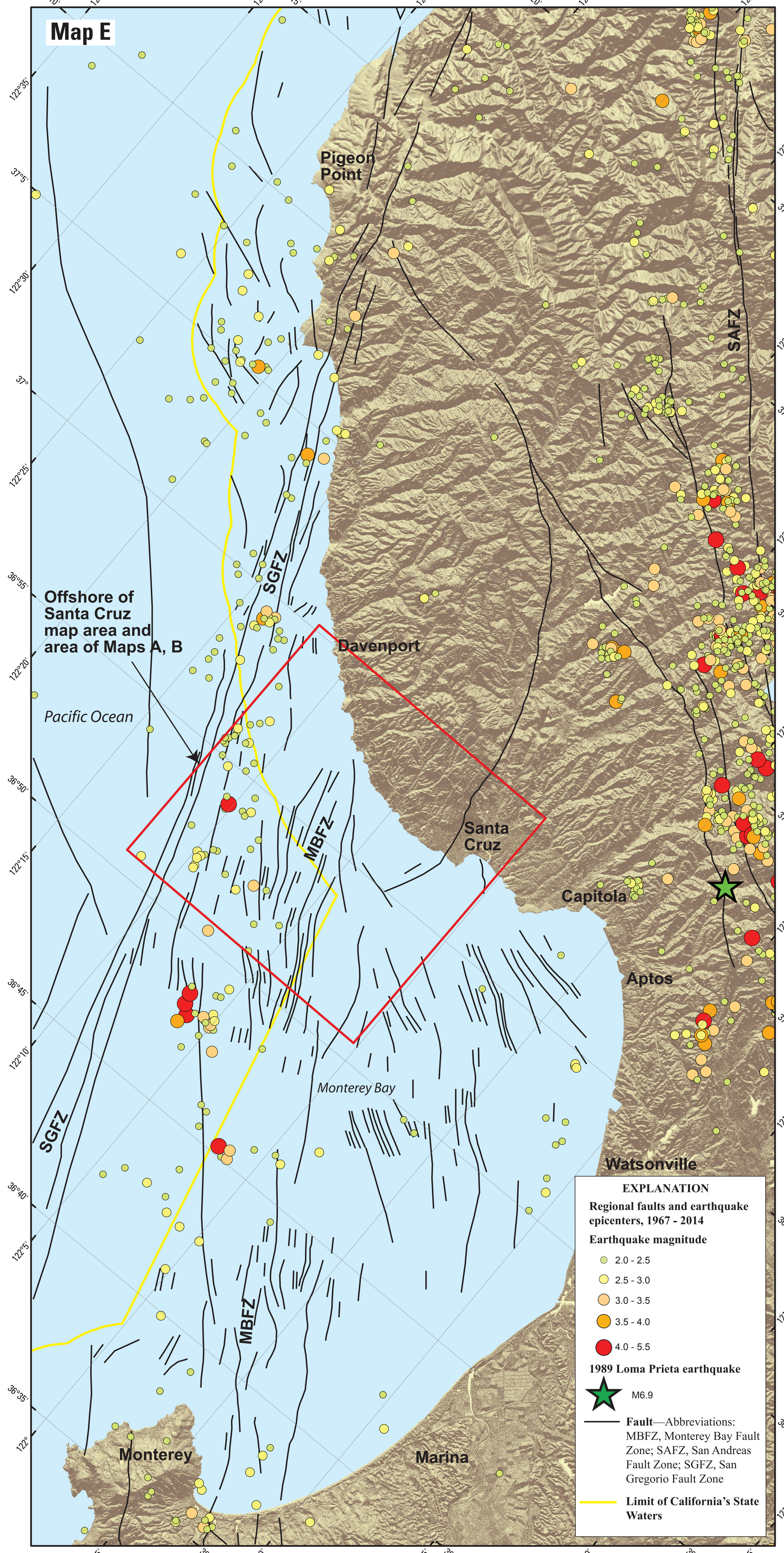


Figure 1. USGS high-resolution minisparker seismic-reflection profile MBS–06 (collected in 2009 on cruise S–N1–09–MB; see fig. 2 on sheet 8), which crosses shelf west of Santa Cruz (see Maps A, B for location). Profile highlights faulted and folded strata beneath continental shelf, including east strands of San Gregorio Fault Zone. Dashed red lines show faults. Magenta symbols show fold axes (diverging arrows, anticlines; converging arrows, syncline). Blue and pink shading shows inferred uppermost Pleistocene and Holocene strata, deposited in about last 30,000 years during final stages of sea-level fall and subsequent sea-level rise. Underlying southwest-dipping reflectors are of Neogene age. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on Maps A, B).







Depth and thickness mapped by Samuel Y. Johnson and Stephen R. Hartwell, 2011–2012
GIS database and digital cartography by Stephen R. Hartwell
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Local (Offshore of Santa Cruz Map Area) and Regional (Offshore from Pigeon Point to Southern Monterey Bay) Shallow-Subsurface Geology and Structure, California

By

Samuel Y. Johnson, Stephen R. Hartwell, Janet T. Watt, Ray W. Sliter, and Katherine L. Maier

2016

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